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A NEW FEATURE OF BUD VARIATION IN CITRUS

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THE WASE VARIETY OF SATSUMA ORANGE.

The Satsuma orange (*Citrus nobilis* Lour. var. *unshiu* Swingle), the Unshiu mikan of the Japanese, is widely grown in Japan, and many different varieties are known to the farmers and nurserymen, among which the Owari and the Ikeda are the most important in commercial culture.

For some 30 years, however, a new variety, called the Wase, has been known. This variety, which is from Aoe (pronounced Ah-o-ey), a village of the Oita prefecture in the Kyushu Island, is liked particularly on account of its early ripening habit and its remarkably polished large-sized fruits.

As a result of the pomological and statistical studies conducted by the writer during 1918 and 1920, the characters of this new commercial variety became very clear, and it can now be distinguished from other varieties of Satsuma oranges by no fewer than 20 independent characters. Its origin was traced to three authentic grafted plants located at Aoe, which furnished the original budwood for propagation. Another grafted plant of this same variety was also found there, which seemed even older than the other trees, and apparently was the mother plant of the three. Nothing is known of the history of this old plant, but judging from the customary method of propagation in early days the budwood must have been taken from some plant growing in the vicinity. The grove in which these trees are growing is the oldest Satsuma orchard the writer ever saw, and huge Satsuma trees were also found in a neighboring orchard, some of them having a spread of as much as 40 feet.

WASE VARIETY PROBABLY THE RESULT OF BUD VARIATION.

It was later discovered, too, that one limb of an Owari tree in Tsukumi, a neighboring village of Aoe, bears typical Wase fruits and that the leaves also correspond with those of the Wase variety.

However, it is clear that there is no relationship between this and the original Wase trees of Aoe, since this sporting branch is so much younger than the latter. A similar striking bud variation of the Owari orange, showing characters of the Wase variety, was observed by the writer at Hisatomomura, Hiroshimaken, Japan, and after a careful examination of progeny propagated vegetatively from these sporting branches at Aoe and Hisatomo the fact is revealed that all the new characters reappear in exactly the same way in plants propagated by grafting. This proves that the characters which originated through bud variation are successfully transmitted by vegetative propagation. A comparison of the commercial Wase orange of Aoe origin with these two recently originated Wase bud variations clearly established their identity and makes it more than probable that the commercial Aoe Wase variety also had its origin as a bud variation, though all record of the original sport is now lost. In comparison with those of the Owari, the fruits of the Wase orange are much larger, smoother, earlier maturing, of lower acidity, and the tree is remarkably prolific, though in growth it appears to be rather stunted.

During the winter of 1920 a thorough investigation was made by the writer in the Satsuma orange districts of Japan, and five more instances of Wase bud variations arising as branches from Owari plants were discovered.¹ The examination of fruits and leaves of these five new Wase bud sports proved them to be all alike in general characters, though slight differences in the shape and size of the fruits were found in some of them. In every case observed the sporting branch was strikingly different in appearance from the rest of the tree—sufficiently different to attract the attention of the grower in each case. Such sports proved to be very rare and in no case did the writer succeed in locating more than one such plant in any one locality where there were growing from 100,000 to 150,000 plants of the Satsuma orange. It is probable, however, that similar bud sports will be found in other localities where the Owari variety is grown commonly, since the writer has already been told of sporting trees which occur in localities he has as yet been unable to visit.

BUD VARIATION MAY BE HORTICULTURALLY BENEFICIAL.

In the light of this discovery it became quite evident that bud variation of Citrus does not limit itself, as has been suggested in many instances previously, to the loss or latency of certain charac-

¹ Trees of the Wase variety of separate origin through bud variation were found at the following places: (1) Sueoka's grove in Ochomura, Hiroshima prefecture; (2) Ishikawa's house garden in Toyodamura, Shidagun, Shidzuoka prefecture; (3) Horie's orchard in Nishimashidzumura of the same county; (4) Hozaki's orchard in Asahatamura, Abegun, Shidzuoka prefecture; and (5) an orchard in Bunzu, Nishihamanamura, Inasagun, Shidzuoka prefecture. Nos. 1 to 4 are now growing in the greenhouses of the United States Department of Agriculture at Washington, D. C., together with the Aoe and Hisatomomura strains, six strains in all.

ters or the production of worthless anomalies, such as variegation, low productivity, lack of juice in the fruit, and wrinkling or corrugation of fruits, but may also result in progressive or beneficial changes from a horticultural point of view, such as increase in the size of the fruit and of the juice vesicles, improvement in the quality of the fruit, increased productivity of the tree, and difference in time of maturity. The origination of the Wase variety by bud variation is sufficient to prove that a novelty produced in this way is sometimes of real agricultural worth, as is evidenced by the fact that the Wase orange industry of Japan has grown in 20 years from nothing to a production of 150,000 yen (\$75,000) worth of fruit annually.

TENDENCY OF THE WASE TO REVERSION.

Since the Wase variety has been grown on a commercial scale in Japan it has been the general experience that a few Owari plants were found mixed in any collection of Wase trees, and as a result of planting such mixtures there are no pure or solid groves of the Wase variety to be found in any part of Japan. This condition was generally charged to dishonesty or carelessness on the part of nurserymen in mixing the plants delivered to the growers, but of late years growers and observers have been claiming that the Wase is not always stable but is changeable—in other words, that two kinds of branches are to be found on some Wase trees, one kind producing typical Wase oranges and the other yielding fruits of a different character.

In 1919 the writer saw here and there such plants, which were pointed out to him by the growers, but the season was too late to permit him to obtain sufficient material to prove anything satisfactorily. One point, however, became clear, namely, that the aberrant plants in the Wase orchards were always of the Owari variety. In no case did the Ikeda or other varieties of the Satsuma orange occur in such Wase groves.

In 1920, when the fruits were all on the trees, the examination and study of the writer were repeated and numerous trees of the Wase variety were found which bore one branch of perfect Owari oranges. Early in October, 1920, the fruits of the Wase variety were partly colored, while those on the Owari branches were still deep green. At the same time the Wase fruits were almost full size and showed the smoothness of peel, the characteristic round shape, and the peculiar stem end which stamped them unmistakably as of the Wase variety. The Owari fruits, on the contrary, were still in a growing condition, characterized by a deeply pitted rind and a rather conical flat outline.

It was noticed that while the Owari branch does not necessarily spring from any definite part of the tree, it usually appears on the

main trunk, either forming a vigorous side branch or upright shoot. Rarely were two such shoots observed on a single plant, and the number of such Wase plants showing a branch of the Owari variety in a grove varied a great deal with the particular condition of the orchard. On well-fertilized bottom land the percentage of such plants was usually very high, but in hillside orchards under rather unfavorable soil conditions it was rather low. Plants of weak growth rarely showed any sign of bud variation, while those making vigorous growth frequently proved unstable. The percentage of such dual plants found in the orchards studied varied from approximately $7\frac{1}{2}$ to $28\frac{1}{2}$.

These observations were made in bearing orchards of the Wase Satsuma orange of Aoe origin, and no study was made of trees of the Wase variety propagated from other bud variations, as they were still too young to use for such observations. The occurrence of a branch having Owari characters on a tree of the Wase variety may easily be conceived of as due to the reversion of certain somatic cells, giving rise to the reverted branch. On this hypothesis these two varieties (Owari and Wase) of the Satsuma orange are reversible with each other, but the chances of maintaining unbroken uniformity in the case of the Wase variety are much less than in the case of the Owari variety.

OTHER REVERSIONS.

This instability of the Wase variety may be explained by its origin through bud variation. The variegation of the Satsuma orange may also be explained in the same way. The writer witnessed a clear case of sporting to the variegated form from a normal green plant, and he has studied elsewhere numerous cases of reversion to green branches from the variegated form.

There is a remarkable bud variation in the Ikeda variety, giving rise to branches with very narrow leaves and elongated fruits. Such a willow-leaved Satsuma tree is not infrequently seen in Ikeda groves, apparently propagated from bud sports of this character, and the reversion of certain branches to the normal form is also definitely recorded.

In the case of sports producing corrugated fruits of the Satsuma orange, the writer has found it difficult to find reversions to the smooth form, as with the Satsuma orange corrugation is less marked than with any other kind of oranges. The reversion of a deeply corrugated variety of Spicy Mandarin (Shûji or Jimikan, in Japanese) to the normal form has been definitely noted, and in this case the normal branch even differs in the size of leaves and fruits from that producing corrugated fruits.

Many instances of bud variation have been reported in horticultural literature, especially with citrus fruits, through the recent investigations of Shamel and his coworkers (12-16).² Shamel also has described a bud variation (analogous to the Wase Satsuma) in the French prune (11), giving rise to a large-fruited type from which occasional reverting branches are produced. As closer studies of such bud sports are made this phenomenon of reversion may be found not infrequent, though but few cases are recorded at present. Correns (3) made a thorough study of variegation in *Mirabilis*, in which he found both bud variation and vegetative reversion very common. Stout (17) in propagating green-leaved bud sports of *Coleus* arising from yellow-leaved plants found the yellow pattern reappearing in a certain number of plants, an occurrence which he called reversion. Wettstein (21) reported the occurrence through bud variation of a fasciated branch upon a normal plant of *Sedum reflexum*. Its seed-propagated progeny showed a tendency to reversion to the normal form, though no vegetative reversion was seen. Reinke (10) reported a striking case of bud variation of a red-flowered individual of *Phaseolus multiflorus*, a branch of which showed no existence of anthocyanin pigment. The new character did not stay constant through seed propagation, but always segregated the original character in the ratio apparently corresponding to a Mendelian recessive. Blakeslee (2) recently found that vegetative reversion occurs in the seed progenies of the dwarf mutant of *Portulaca grandiflora*. He found only a single case of original mutation among thousands of normal plants, but the individuals with reverting branches constituted 1.23 per cent of the progeny of the mutant. His genetic study confirms the belief that the dwarf character is clearly recessive to normal, and the reverted normal is heterozygous with respect to dwarfness. No explanation as to regaining heterozygosity from a homozygous dwarf is presented, though he believes that the original mutation might have occurred on a heterozygous normal plant. Likewise, bud variation is often considered as occurring more frequently in the case of heterozygous plants than with the homozygous individual, as pointed out by East (7), but we still have evidence that it may arise in pure-line individuals, as Johannsen (9) discovered in *Phaseolus vulgaris*.

POSSIBLE EXPLANATIONS OF BUD VARIATION.

There are several explanations as to the process of bud variation. East (5) first presented the idea that bud variation is the same as germinal mutation, the only difference being that it happens in a

² The serial numbers in parentheses (italic) refer to "Literature cited" at the end of this circular.

somatic cell. Emerson's experiments with variegated ears of maize (8) presented some proof of this possibility. Bateson (1), on the other hand, introduced the conception of somatic segregation of a Mendelian recessive, and later experiments of East (6) appear to be in favor of this hypothesis. Stout (18) suggested, however, the possibility that some cases of bud variation occur in the form of periclinal chimeras. Later he discovered an apple tree with two kinds of branches, which he attributed to chimeric origin (19). After Winkler's epoch-making discovery of plant chimeras, many phenomena of unknown origin were attributed to chimeras, with insufficient justification, but the existence and importance of the chimera in practical breeding remain beyond doubt, as is illustrated in Winkler's final paper (23), summarizing all his previous investigations.

The first explanation (a change occurring in a somatic cell) seems well adapted to explain the appearance of a simple recessive character through bud variation, but in a case like that of the Wase Satsuma orange the characters are much too complicated to be explained by a simple loss of dominancy by mutation. From every viewpoint the fruit of the Wase Satsuma orange represents a progressive, not a degressive, change, and the Wase characters are apparently complex. Does this represent a case of progressive somatic mutation? Is the factor complex so closely linked as to bring about a simultaneous change, or does the mutation of different factors occur simultaneously? If it be a case of somatic segregation, what basis is there for regarding the Owari variety as a hybrid? Or is the origination of the Wase variety simply the reappearance of a long-lost ancestral character, as instanced by Darwin (4)?

If, however, the Wase variety should be a periclinal chimera, what sort of progeny should we obtain from a pure Wase branch, such as is often found on chimeric plants through vegetative segregation, as shown by De Vries (20) in the case of *Cytisus adami* or by Winkler (22) in *Solanum tubigense* and *S. proteus*?

To solve these and related problems would require no little time and work, but the result of such an investigation will be of vital interest to breeders, pomologists, and orchardists.

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